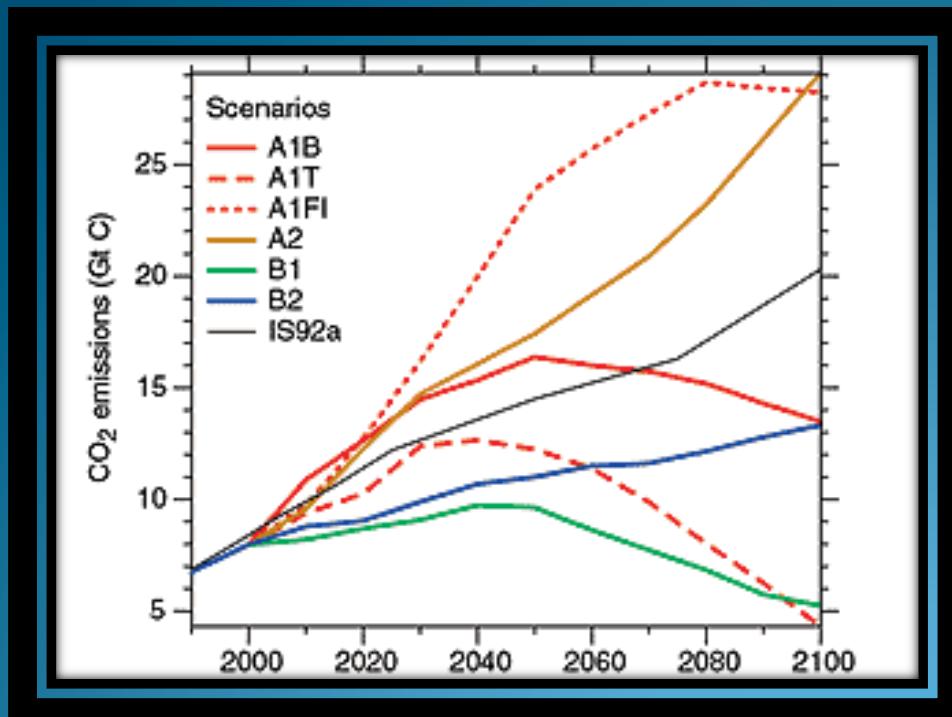


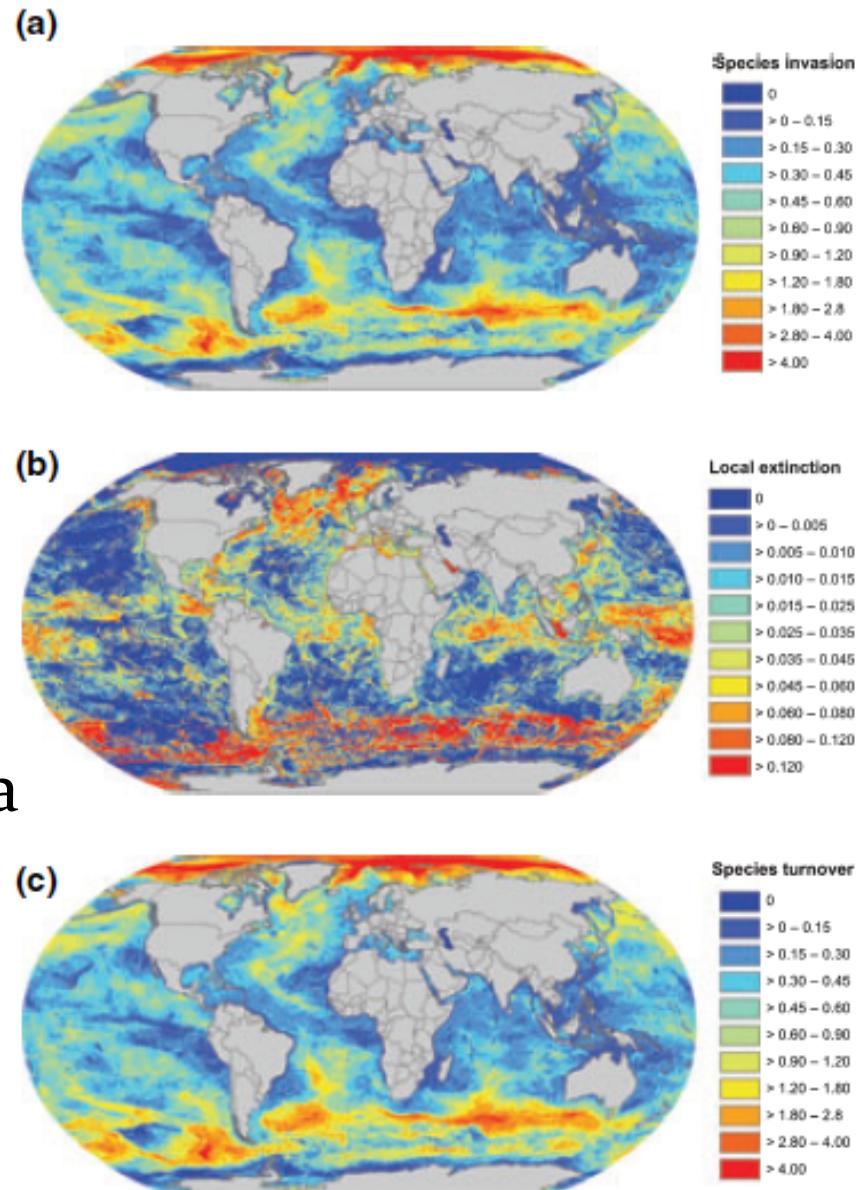
# Projecting the impacts of climate change on fish, fisheries and marine ecosystems



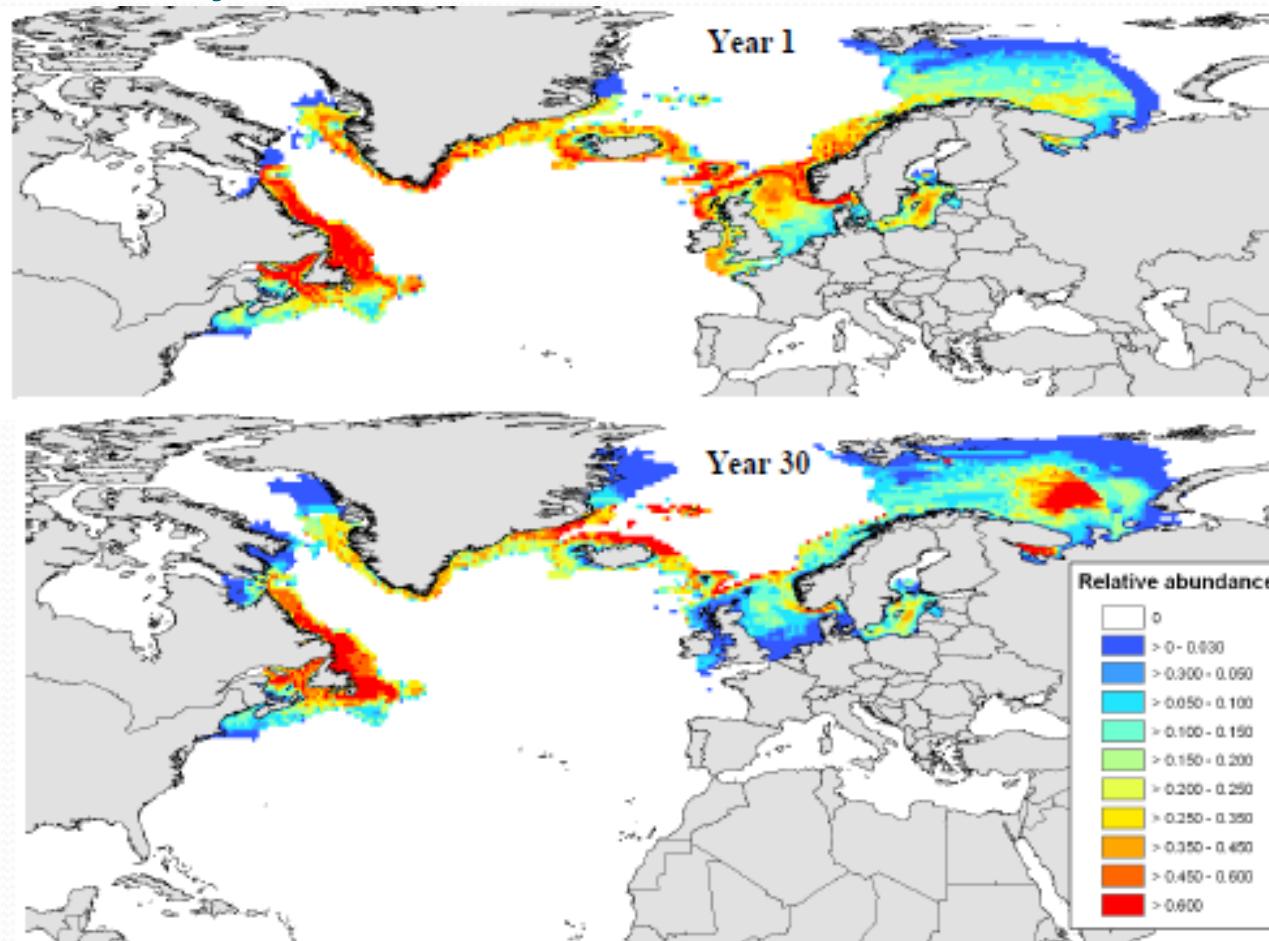
Janet Nye  
Stony Brook University  
December 2, 2014

# Cheung's projections of changes in global biodiversity

- 1 GCM (GFDL CM 2.1)
- Simple model of population growth (logistic population growth)
- Bioclimatic envelope based on SST, salinity, sea ice cover, ocean advection, bathymetry, habitat



# Cheung's projections of changes in global biodiversity-Atlantic cod

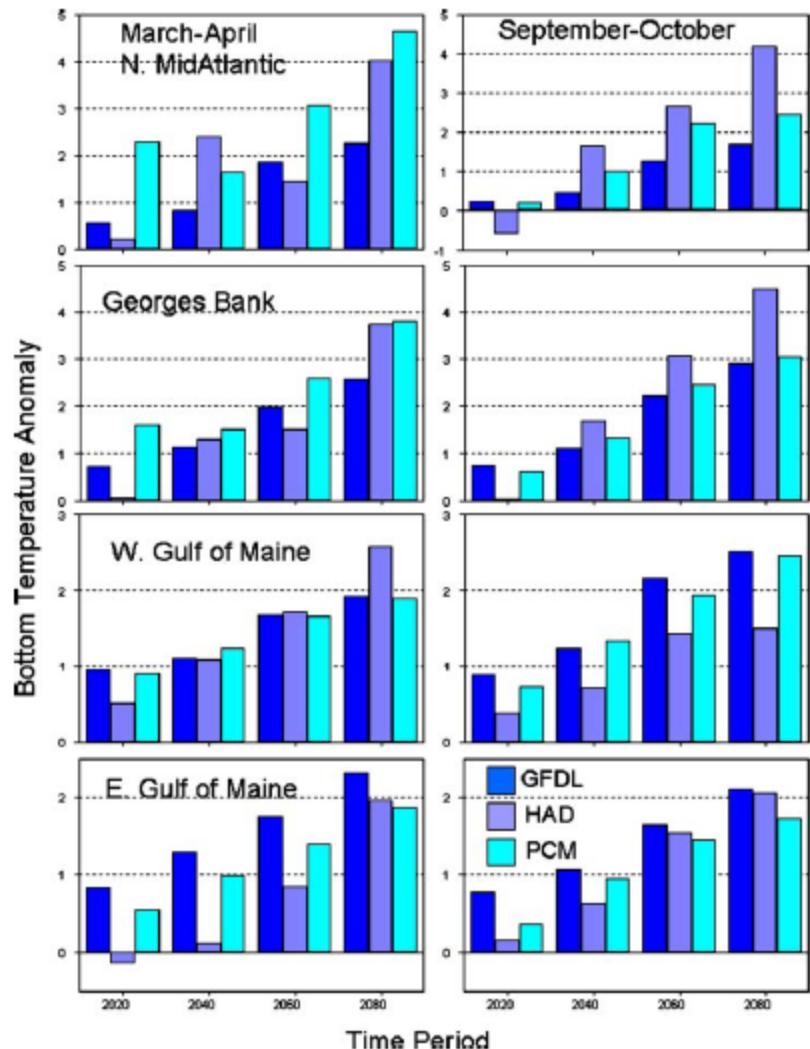


Cheung, W.W.L., Lam, V.W.Y., Pauly, D., 2008. Modelling present and climate-shifted distribution of marine fishes and invertebrates. Vancouver, B.C., Canada: Fisheries Centre Research Reports, p. 72.

# Potential climate change impacts on Atlantic cod (*Gadus morhua*) off the northeastern USA.

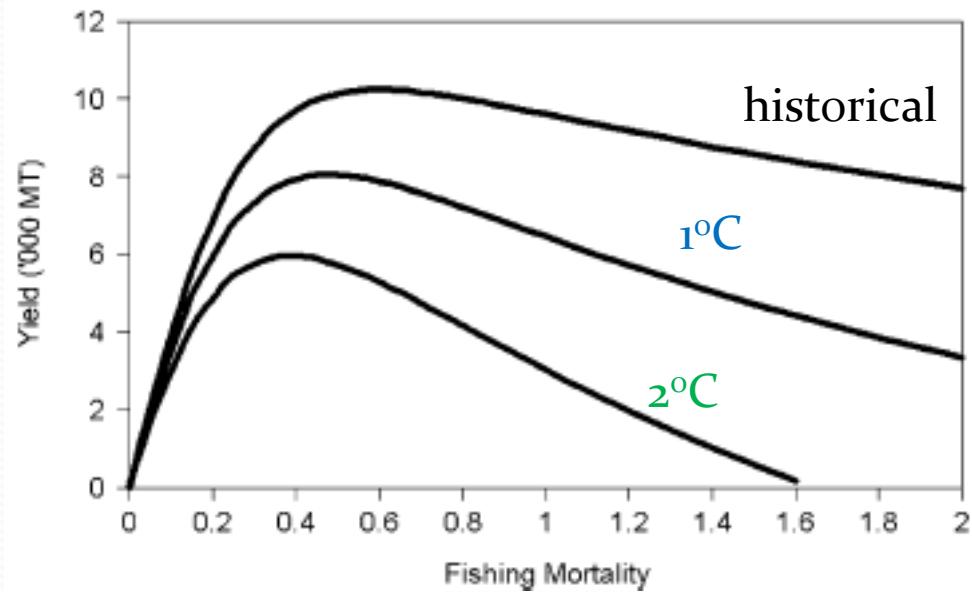
Fogarty, M. L. Incze, K. Hayhoe, D. Mountain and J. Manning. 2008.

- Three climate models examined
- Linear regression of observed data used to predict BT from SST
- SST from GCMs converted to BT for 4 regions and 2 seasons



# Atlantic cod in Northeast US

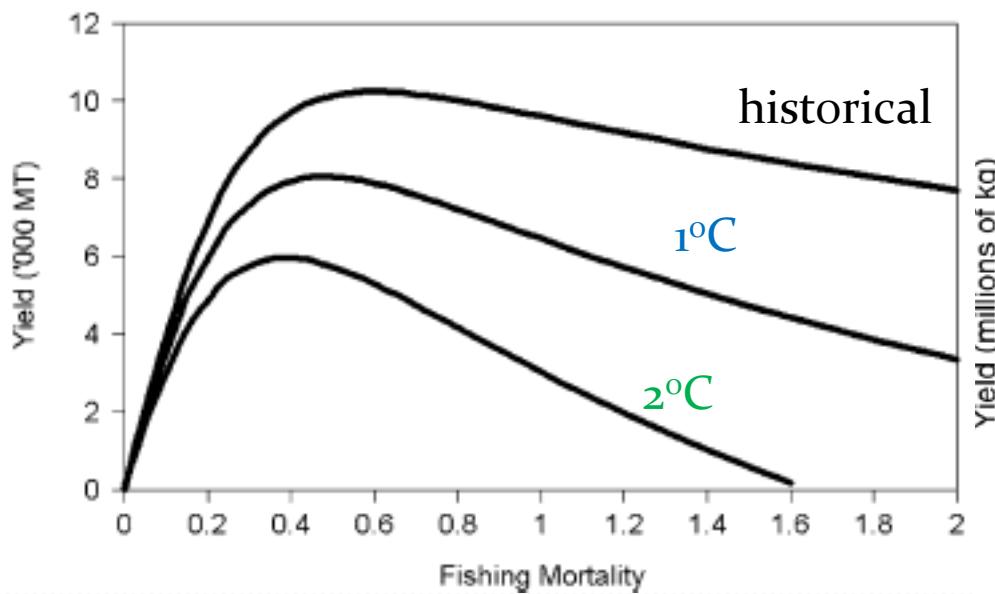
- Effect of temperature incorporated into growth and recruitment
- Predicted cod yield at three different temperatures
- Also projected change in distribution



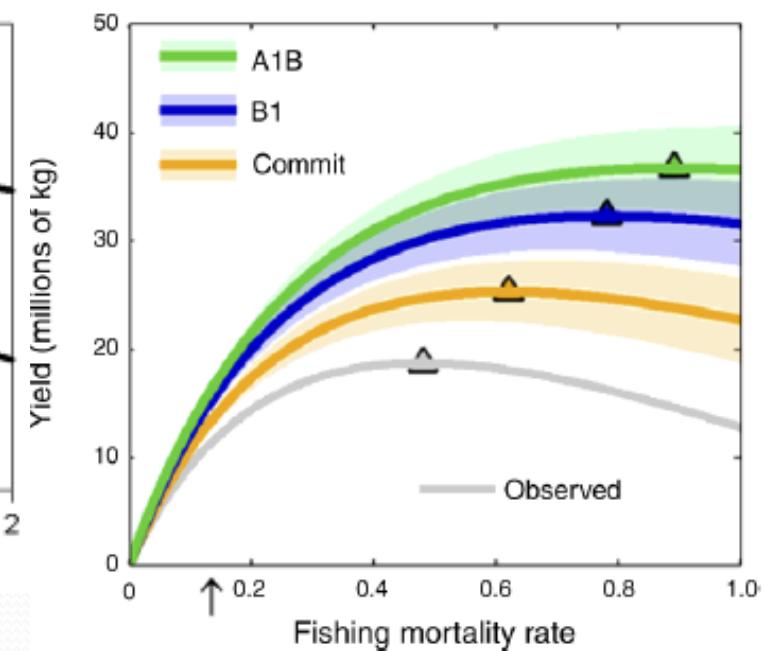
# Forecasting the dynamics of a coastal fishery species using a coupled climate–population model

JONATHAN A. HARE,<sup>1,5</sup> MICHAEL A. ALEXANDER,<sup>2</sup> MICHAEL J. FOGARTY,<sup>3</sup> ERIK H. WILLIAMS,<sup>4</sup> AND JAMES D. SCOTT<sup>2</sup>

## Atlantic cod



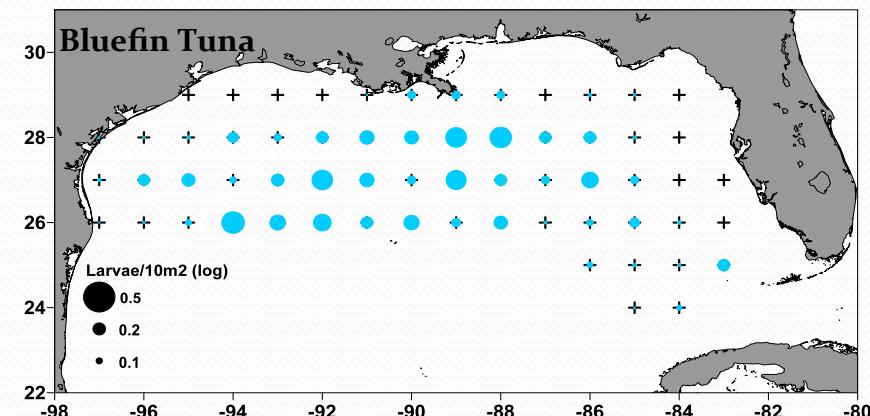
## Atlantic croaker



- Fogarty et al. 2008

# Distribution-based approach

- Develop habitat model and project habitat and maybe abundance
- For data poor species
- For rapid “assessment”
- Endangered Species Act applications
  - Cusk *Brosme brosme*
  - River herring (alewife and blueback herring)
- Highly migratory species
  - Bluefin tuna
  - Yellowfin and blackfin tuna
  - Skipjack tuna





# Cusk (*Brosme brosme*) and climate change: assessing the threat to a candidate marine fish species under the US Endangered Species Act

Jonathan A. Hare<sup>1\*</sup>, John P. Manderson<sup>2</sup>, Janet A. Nye<sup>3</sup>, Michael A. Alexander<sup>4</sup>, Peter J. Auster<sup>5,6</sup>, Diane L. Borggaard<sup>7</sup>, Antonietta M. Capotondi<sup>4</sup>, Kimberly B. Damon-Randall<sup>7</sup>, Eric Heupel<sup>5</sup>, Ivan Mateo<sup>7†</sup>, Loretta O'Brien<sup>8</sup>, David E. Richardson<sup>1</sup>, Charles A. Stock<sup>9</sup>, and Sarah T. Biegel<sup>7</sup>

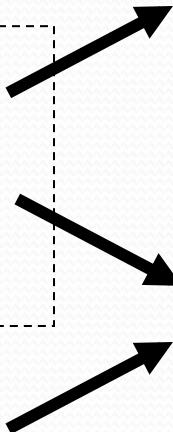
Bottom type

Static Field

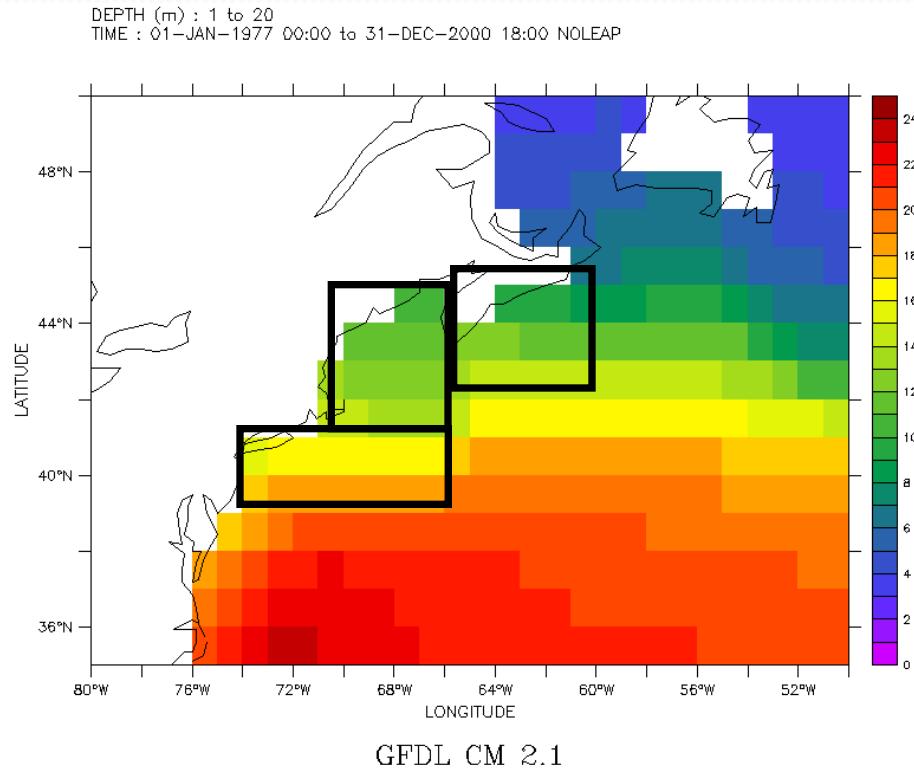
Habitat Model  
(GAM)

Temperature  
at depth

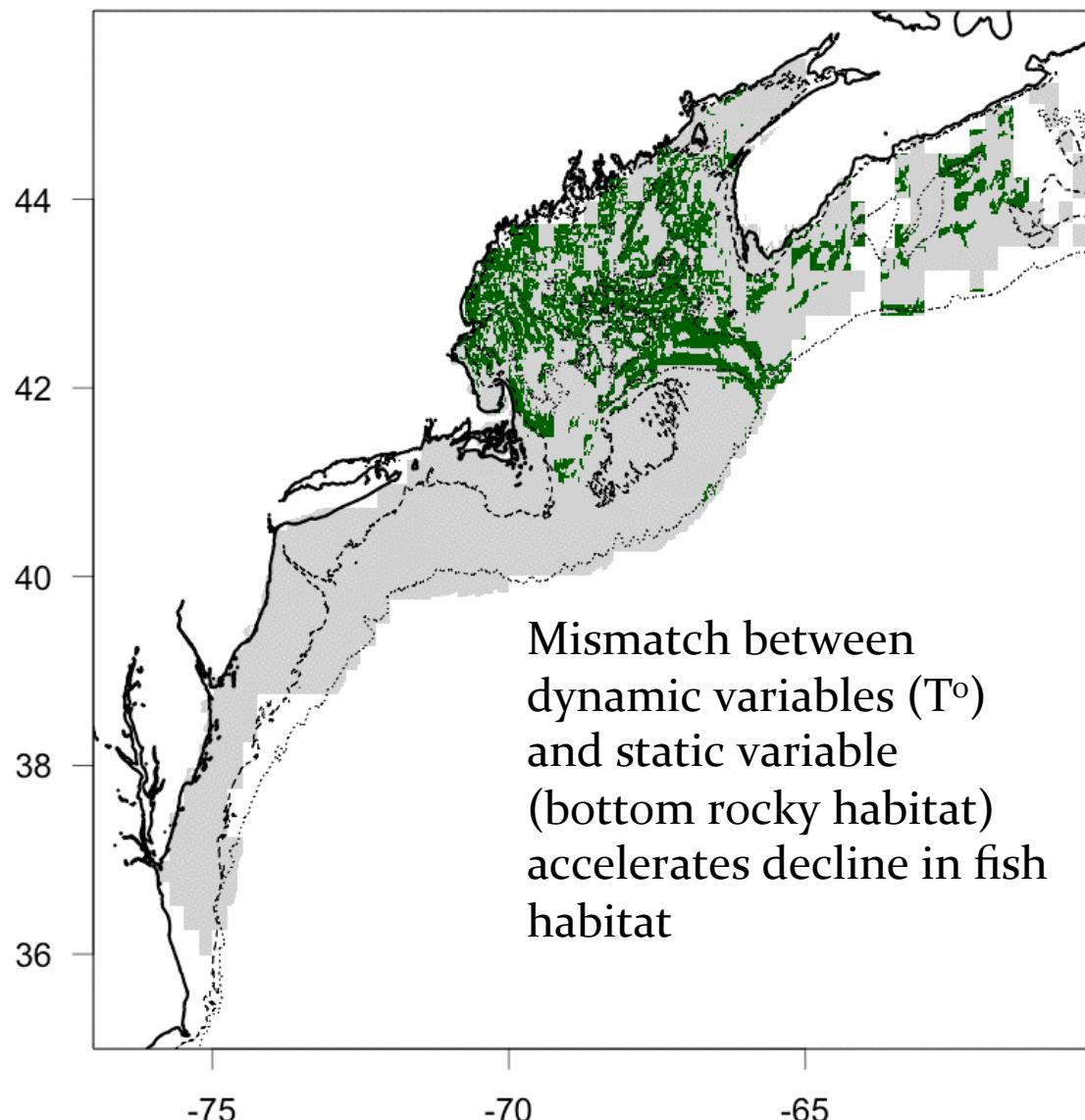
Dynamic Field



Climate Models



## Potential habitat NovDec



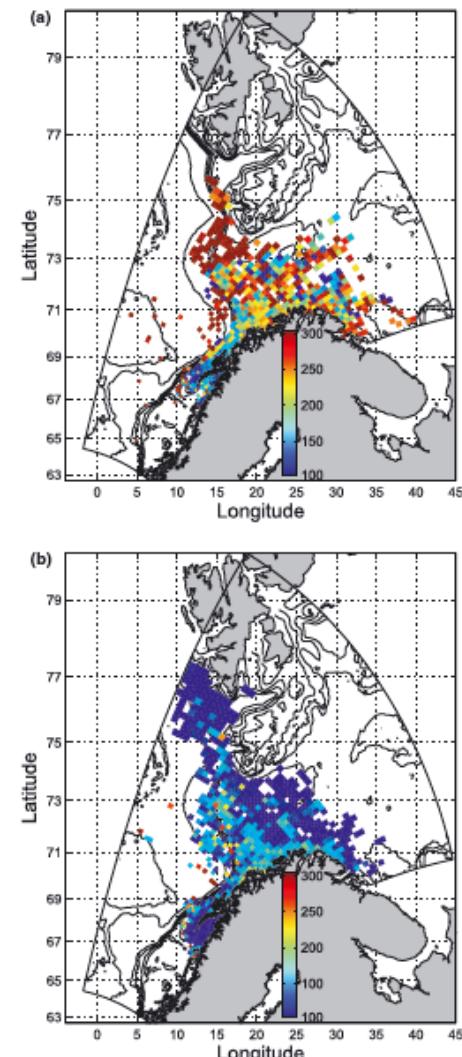
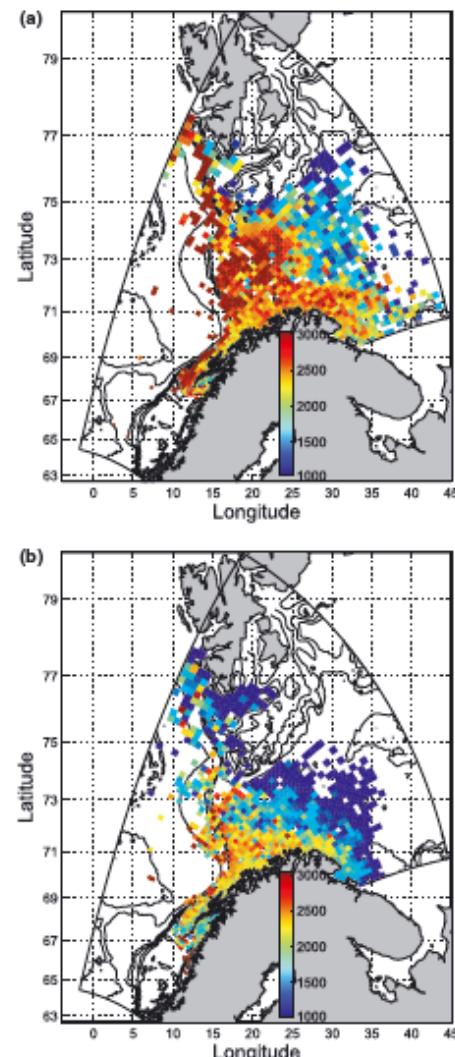
# Sources of variability

Factor	Proportion variance explained	Number of levels
Region	0.002	3 (SNE, GOM, ScS)
Scenario	0.052	3 (A2, A1B, B1)
Time period	0.396	2 (2060, 2100)
Depth	0.012	12
Season	0	6
GCM	0.183	7
Error	0.354	
Total	1	

# Impacts of a reduced thermohaline circulation on transport and growth of larvae and pelagic juveniles of Arcto-Norwegian cod (*Gadus morhua*)

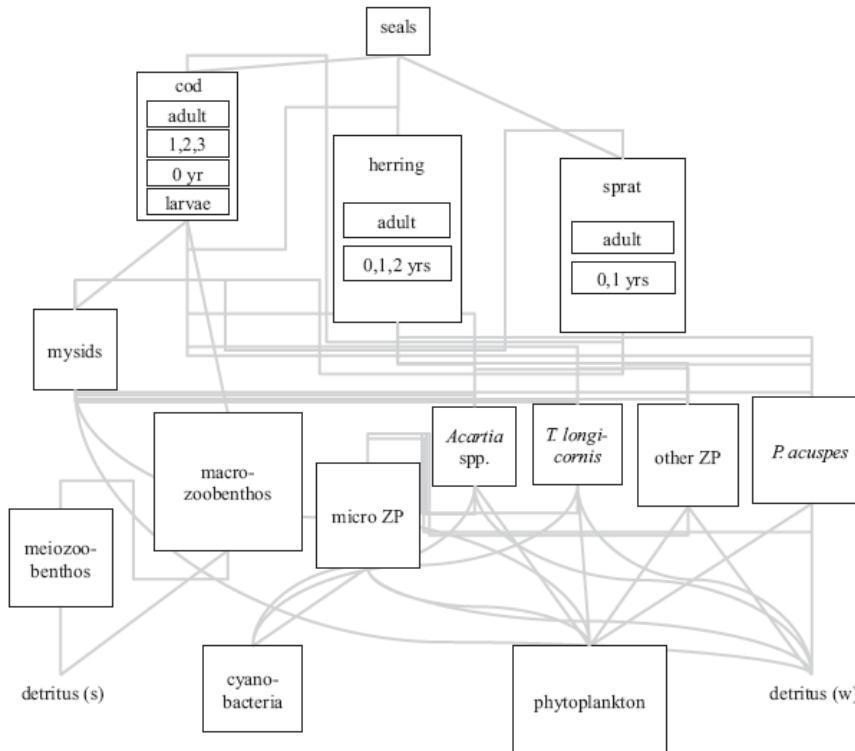
F. B. VIKEBØ,<sup>1,\*</sup> S. SUNDBY,<sup>2</sup> BJØRN  
ÅDLANDSVIK<sup>2</sup> AND O. H. OTTERÅ<sup>3</sup>

- IBM
- THC weakened by increasing river flow threefold
- Main effects were temperature and advection
- Response was on growth, abundance and spatial distribution



# Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

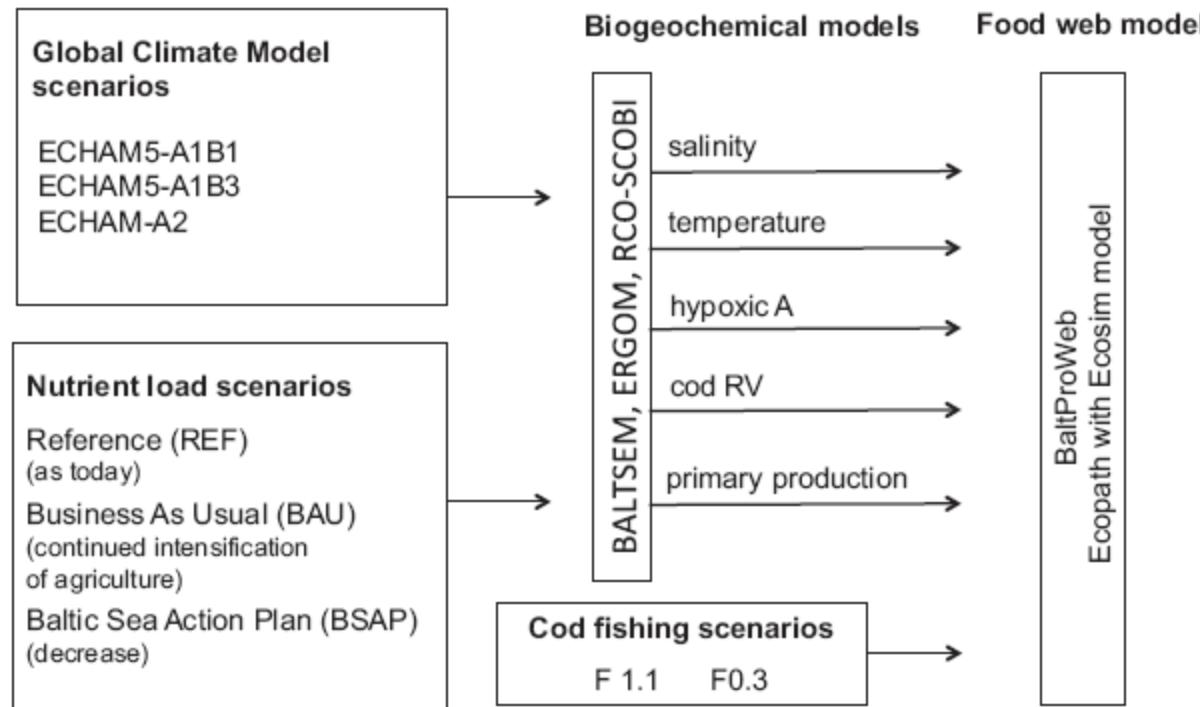
SUSA NIIRANEN\*†, JOHANNA YLETYINEN\*‡, MACIEJ T. TOMCZAK§, THORSTEN BLENCKNER\*, OLLE HJERNE†, BRIAN R. MACKENZIE¶, BÄRBEL MÜLLER-KARULIS§, THOMAS NEUMANN|| and H. E. MARKUS MEIER\*\*††



- Food web model  
(Ecopath with Ecosim)
- Dynamical downscaling
- Multiple stressors-  
nutrient runoff, fishing  
and climate
- But a relatively simple  
food web!

# Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

SUSA NIIRANEN\*†, JOHANNA YLETYINEN\*‡, MACIEJ T. TOMCZAK§, THORSTEN BLENCKNER\*, OLLE HJERNE†, BRIAN R. MACKENZIE¶, BÄRBEL MÜLLER-KARULIS§, THOMAS NEUMANN|| and H. E. MARKUS MEIER\*\*††



# Combined effects of global climate change and regional ecosystem drivers on an exploited marine food web

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**Table 3** The average biomass trends of selected groups for near (2020–2049) and far (2070–2098) future in different management scenarios for nutrient loads

Group	2020–2049						2070–2098					
	REF		BAU		BSAP		REF		BAU		BSAP	
	$F_{1.1}$	$F_{0.3}$										
Adult cod	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑
Adult herring	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓
Adult sprat	↑	—	↑	↑	↑	↓	↑	↑	↑	↑	↑	—
<i>Pseudocalanus acuspes</i>	—	↑	—	↑	↓	↑	↓	—	↓	—	↓	—
<i>Acartia</i> spp.	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Other mesozooplankton	—	↑	—	↑	—	↑	↓	↑	↓	↑	↓	↑
Phytoplankton	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

REF, reference; BAU, business as usual; BSAP, Baltic Sea Action Plan; for cod fishing:  $F_{1.1}$  = intensive fishing,  $F_{0.3}$  = recovery plan. Arrows indicate a decrease or increase in biomass from 1974–2006 (black arrow =  $\pm 10\text{--}49\%$ , red arrow  $\pm \geq 50\%$ ) and ‘—’ indicates no change in biomass ( $\max \pm 10\%$ ).

# Conclusions

Focus has been on temperature

- Incorporate additional variables (salinity, advection) or use Earth System models to look at stratification, plankton assemblages

Focus on means

- Extremes may cause regime shifts that are ultimately more important in structuring ecosystems than changes in mean

The issue of scale

- Need finer scale models and/or dynamical downscaling
- Use large-scale oceanographic features that are well-represented in GCMs and that have been shown to structure ecosystems

**Move beyond single species → ecosystem models**

**Use a multi-model inference approach**

	Species	Downscale method	Scenario	Geographical area	# GCMs	Climate and stressor variables	Bio/Ecological model
Cheung et al. 2008	Many	None	Commit, B1, A1B	Global	1	SST + 6 others	Logistic pop. growth
Fogarty et al. 2008	Atlantic cod	Δ	A1Fi, A2, B1	Northeast US coast	4	T°	Growth, SR, distribution
Hare et al. 2010	Atlantic croaker	Δ	Commit, B1, A1B	Northeast US	14	T°	SR, distribution
Hare et al. 2012a	Gray snapper	Δ	Commit, B1, A1B	Southeast US coast	14	T°	Habitat
Hare et al. 2012b	Cusk	Δ	B1, A1B, A2	Northeast US coast	7	T° (and bottom type)	Habitat
Lynch et al. in press	River herring	Δ	B1, A1B, A2	Northeast US coast	7	T°	Habitat
Vikebo et al. 2007	Atlantic cod	Δ	THC	Arctic/Nordic Sea	1	Reduced THC, increase river runoff	Individual based model (IBM)
Muhling et al. 2011	3 tuna species	Δ (weighted)	A1B	Gulf of Mexico	20	T°	Habitat
Mackenzie et al. 2012	Sprat	Dynamical	A1B	Baltic Sea	1 + 1	T°	Age structured model, SR
Diamond et al. 2014	Atlantic croaker	Δ	A2,A1B,B1	Southeast US coast	3	T°, hypoxia, salinity, sea level rise and ocean circulation	Nonlinear matrix model
Kristiansen et al. 2014	Atlantic cod	ESM		5 stocks in North Atlantic	1	T°, stratification, zooplankton size class	Individual based model (IBM)
Niiranen et al. 2013	Baltic sea food web	Dynamical	A1B, A2	Baltic Sea	1 + 3	To, salinity, hypoxia, fishing, primary prod.	Ecopath w/ Ecosim